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PRELIMINARY INVESTIGATION OF SEWAGE SLUDGE DUMPING OFF DELAWARE BAY

Ralph W. Buelow, et al

Northeast Marine Health Science Laboratory
Narragansett, Rhode Island

January 1968

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National Center for Urban and Industrial Health

Water Supply and Sea Resources Program

PRELIMINARY INVESTIGATION OF SEWAGE SLUDGE DUMPING OFF DELAWARE BAY

by

Ralph W. Buelow, Sanitary Engineer
Benjamin H. Pringle-Ph.D., Supervisory Chemist
James L. Verber, Oceanographer

Northeast Marine Health Sciences Laboratory
Narragansett, Rhode Island 02882

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ERRATA

Preliminary Investigations of Sewage Sludge Dumping off Delaware Bay

P.4 Corrections in Table 2:

Date 1967	Time of Barge at Mouth of Delaware Bay		Time of Trip	Time Between Trips
	EDST		Hours-Minutes	
	OUT	RETURN		
May 28	1810	2230		
30	0530	0930		
31	2350			

P.9 3rd Paragraph, 3rd line, or instead of on "surf clam beds or towards...."

TABLE OF CONTENTS

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	Page No.
INTRODUCTION	1
DESCRIPTION OF INVESTIGATION	3
BACTERIOLOGICAL RESULTS	6
HYDROGRAPHIC CONDITIONS	9
CHEMICAL ANALYSIS	11
CONCLUSIONS	13
RECOMMENDATIONS	16
APPENDIX	18
BIBLIOGRAPHY	21

LIST OF TABLES

Table No.	Description	Page No.
1	Volumes of Sewage Sludge	3
2	Sewage Sludge Dumping Times	4
3	Bacteriological Water Quality	6
4	Clam Bacteriological Results	7
5	Bacteriological Water Quality Following a Dump	8
6	Normal Heavy Metals in Hard Clams	11
7	Heavy Metals in Surf Clam Samples	12
A-1	Complete Water Sample Data	18

LIST OF FIGURES

Figure No.	Description	After Page No.
1	Surf Clam Areas	2
2	Sewage Sludge Dump Locations	3
3	Sampling Station Locations	3

INTRODUCTION

Requests from Region II Water Supply and Sea Resources Program, the shellfish sanitation agencies in the states of Region II, the shellfish industry and others interested in the pollution potential of sewage sludge, chemical wastes and other wastes being dumped offshore in the Atlantic Ocean were responsible for NEMHSL, FRD section undertaking an investigation of the waters off Delaware Bay receiving sewage sludge by barge.

Conferences on waste dumping off the New Jersey coast were held 10 March 1966, 23 May 1966, and 10 August 1966. Some or all of these conferences were attended by the following

United States Army Corps of Engineers
New Jersey State Health Department
New Jersey State Department of Conservation and Economic Development
FWPCA Delaware River Basin Commission
U.S.P.H.S., Water Supply and Sea Resources
Philadelphia Port Corporation
FWPCA Hudson-Champlain Project
Delaware State Board of Health
Oyster Institute of America
New York State Conservation Department
United States Coast Guard
Delaware Water and Air Resources Commission
City of Baltimore, Maryland
City of Philadelphia
Towing Companies Representatives
Clam Industry Representatives

The initial conference was called to exchange information on the subject of ocean disposal of wastes, discuss the problems it presents and how to control such operations. At this meeting it was decided that the U.S.P.H.S. should develop guidelines for use in control of waste dumping in the Atlantic Ocean. At this time Field Research and Development, NEMHSL, had scheduled a study of the New York Metropolitan Area Sewage Sludge Dump for May 1966 in response to the previously described requests. This study was a very limited preliminary venture to gain some insight as to the scope of the problem and produce some indication of the area polluted bacteriologically by the sewage sludge. The bottom in the sludge dump area was for the most part covered with mud and sludge deposits that eliminate the surf clam, which is a sand and gravel bottom creature. Until a thorough study of sediment movements could be made, it was decided that nothing could be gained by relocating the New York Bight dump site.

The next two meetings covered all the known dumping operations cleared through the Corps of Engineers but were primarily pointed at the future potential problem of dumping of sewage sludge off Delaware Bay. The

cities of Philadelphia, Pennsylvania, and Camden, New Jersey, were already dumping in a designated area and Baltimore, Maryland, proposed dumping in the same area beginning in 1970. The attention of NEMHSL was also directed toward this area of main interest and the investigation described in this report resulted. The general opinion seemed to be that areas presently uncontaminated by wastes should remain so.

A proposal of a transportation company to haul wastes by rail and truck for disposal at sea also increased concern for overloading certain ocean areas with waste materials. The waste products to be hauled by the transportation company were classified as (1) city sludge, (2) inert industrial waste, (3) alkali waste, and (4) acid waste.

Those interested in protection of the shellfish in our estuarine and offshore waters have a very real concern regarding disposal of wastes in shellfish producing waters. The Surf Clam or Sea Clam, Spisula solidissima, grows in an extensive area along the east coast of the United States as shown in Figure 1.

The 1966 harvest of 45,000,000 pounds of surf clam meats, which is 32 per cent of the United States shellfish harvested, attests to its commercial importance. Oysters are the only shellfish with a greater harvest (Bureau of Commercial Fisheries, 1967). In dollar value the surf clam ranked with the soft clam at around $4 million.

Plans are being considered for using sections of lower Delaware Bay for hard shell clam relaying and growing beds. Those involved in this plan have concern about the effect wastes dumped off Delaware Bay could have on such an operation.

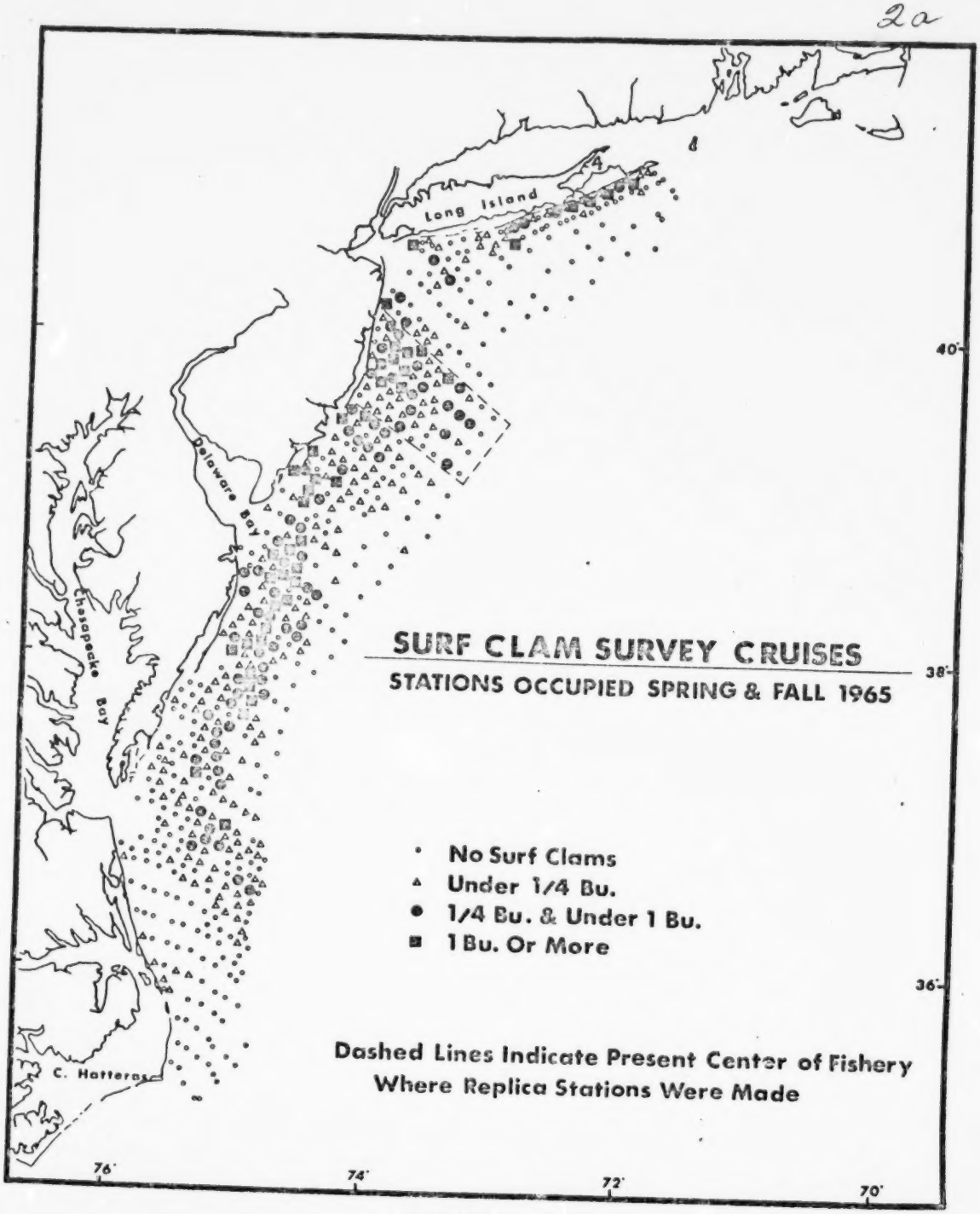


FIGURE 1

(Taken from the United States Bureau of Commercial Fisheries Biological Laboratory, Oxford, Maryland, Technical Report, Progress in Surf Clam Biological Research, June 1966.)

DESCRIPTION OF INVESTIGATION

The Delaware Bay investigation was planned for two weeks at the end of May and early June 1967. It was designed as a preliminary investigation to define the problem and intended to determine distribution of bacterial pollution resulting from the discharge of sewage sludge in the designated disposal area.

The University of Delaware Marine Laboratory Research Vessel, Wolverine, was chartered. The Wolverine was moored at the University of Delaware Bayside Marine Laboratory at Lewes, Delaware, and for convenience the FRD mobile laboratory was located at the Bayside Laboratory.

The main objective of a health agency in this case is to prevent bacterial, virological, chemical and toxicological contamination of edible shellfish and other marine food products. When shellfish producing areas are adjacent to known pollution sources, adequate closure lines should be established to prevent harvesting of potentially unsafe shellfish. When steps are taken to eliminate the pollution, the areas can be considered for reopening. Commercially important surf clam beds are found in the areas surrounding the present dump site and in much of the area extending some distance offshore as shown on Figure 1 (Bureau of Commercial Fisheries, 1966).

The sludge dump area investigated is shown in Figures 2 and 3. Figure 2 shows the area in relation to the coastline whereas Figure 3 presents the dump area and sample stations. The dump area is described by the Corps of Engineers as follows: "It is 6,000 feet wide and 12,000 feet long, the longer side bearing North 36°52' East (true). The center of the area is at latitude 38°45.6' North, longitude 74°47.3' West, and is 11.8 nautical miles from Bell Buoy R '4' near Overfalls Shoal on a course bearing East 18°17' South (true)."

Present and proposed volumes of sewage sludge for disposal in this area are listed in the following Table 1:

TABLE 1

Volumes of Sewage Sludge Being Dumped or Proposed for Dumping

Source	Yearly Volume (cu. yd.)	Status of Dumping
City of Philadelphia, Pa.	446,000	In Operation
City of Camden, New Jersey	69,000	In Operation
City of Baltimore, Md.	495,000	Planned for 1970
Reading Company	Unknown	Proposal Submitted

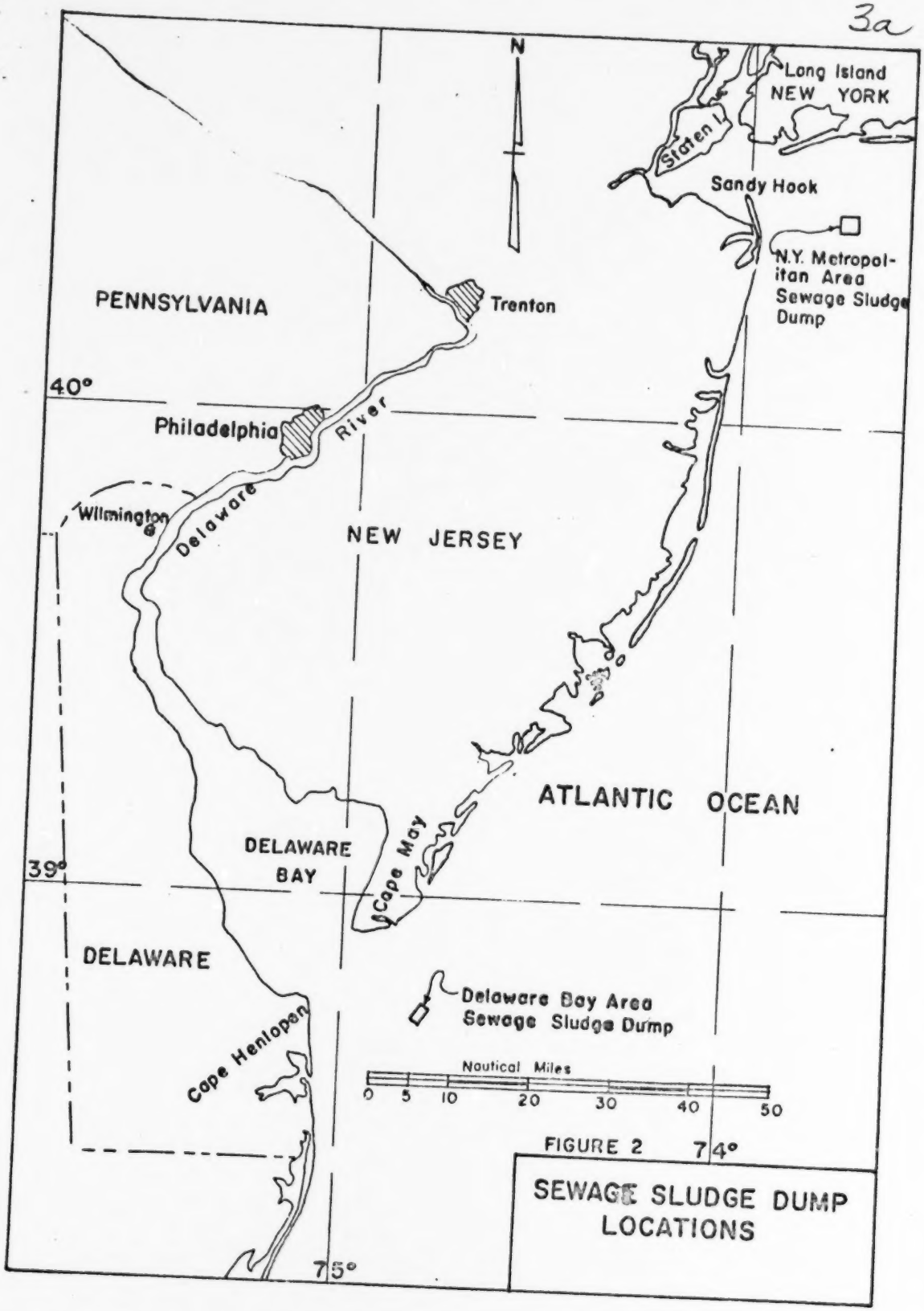
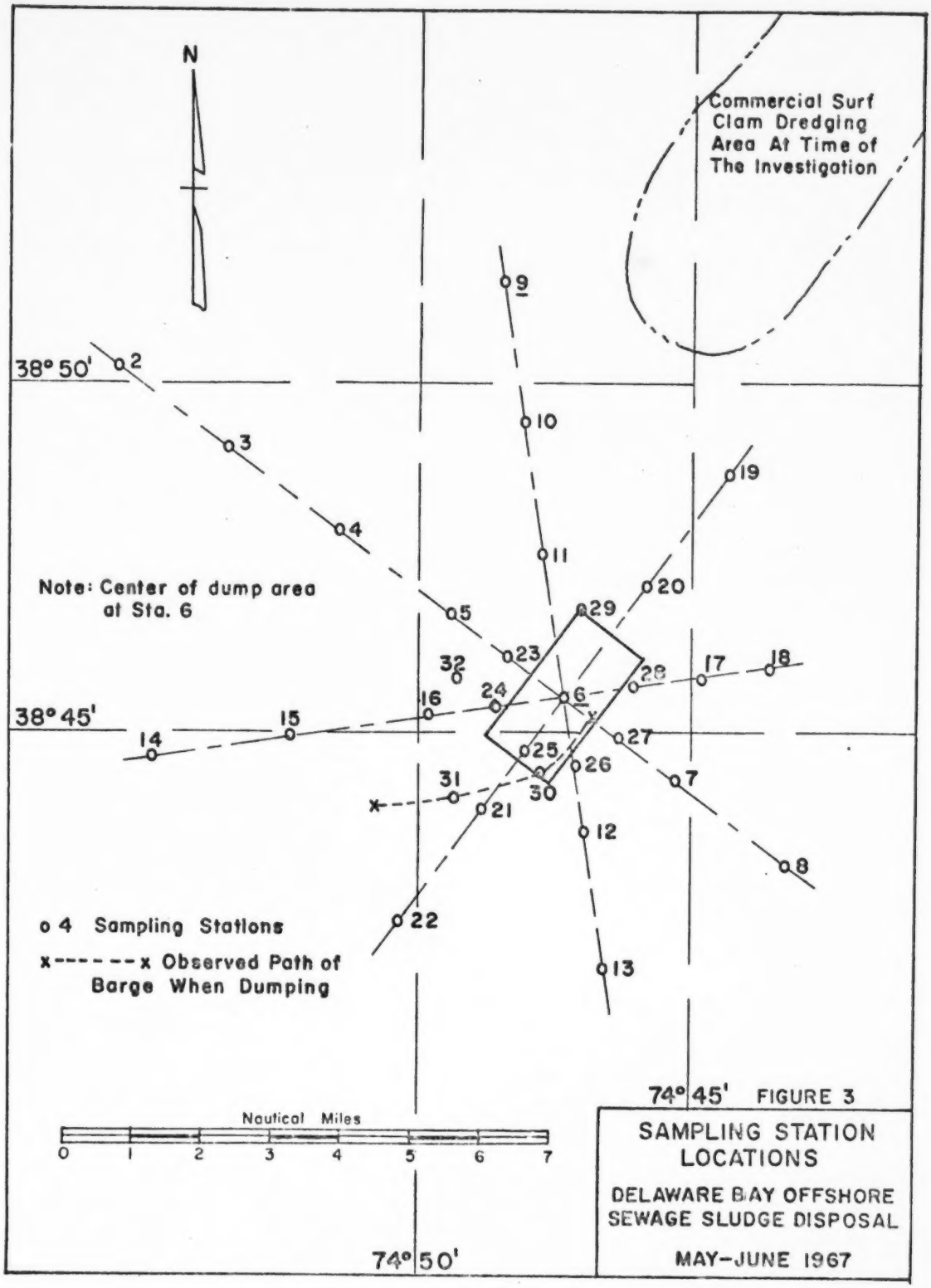


FIGURE 2

SEWAGE SLUDGE DUMP LOCATIONS


N
Commercial Surf Clam Dredging Area At Time of The Investigation
38° 50'
38° 45'
74° 45'
74° 50'
Note: Center of dump area at Sta. 6
o 4 Sampling Stations
x------x Observed Path of Barge When Dumping
Nautical Miles
0 1 2 3 4 5 6 7
FIGURE 3
SAMPLING STATION LOCATIONS
DELAWARE BAY OFFSHORE SEWAGE SLUDGE DISPOSAL
MAY-JUNE 1967

The Corps of Engineers provided information that the Philadelphia sewage sludge was being barged by the Hayes Towing Company. Through the willing cooperation of the Lewes Coast Guard Station and the Lewes Maritime Tower the name of the tug and the barge were determined. During the time of the investigation the tug, Prince, and barge, Raritan, were being used.

The schedule of the times for the barge trips during the study are listed in the following Table 2:

TABLE 2

Times of Sewage Sludge Dumpings During Time of Investigation

Date 1967	Time of Barge at Mouth of Delaware Bay EDST		Time of Trip		Time Between Trips	
	OUT	RETURN	Hour-Minutes		Hours	Minutes
May 22	0230	0640	4	10		
27	0045	0525	4	40		
28	0530	2230	4	20	36	45
30	2350	0930	4	00	31	00
31						
June 1		0420	4	30	38	20
3	1015	1430	4	15	53	55
5	0300	0730	4	30	36	10
7	0900	1330	4	30	54	00

The barge carried a load of approximately 700,000 gallons per trip.

The investigation was begun by collection of surf clam samples by dredging with a weighted blade dredge. An attempt was made to collect clams at as many of the stations shown on Figure 3 as time and conditions permitted. Some stations were not dredged because they were in cable or danger areas. The clam dredging was undertaken first because it was the most difficult of the sampling operations and to take advantage of good weather for the dredging. Also, while dredging operations were proceeding, the sampling schedule could have been altered to permit water sampling if any barge arrived to dump sludge.

Clam samples were taken for bacterial analysis in the mobile laboratory. Duplicate samples were shucked on the vessel and frozen for chemical analysis at NEMHSL.

Following two days of clam sampling, water quality sampling was begun. Water samples at all the stations were to be collected at least twice for surface, mid-depth, and bottom. Samples at one-half the stations were to be collected on the first two runs and the remaining ones the next two days of sampling.

There was extreme difficulty in finding a barge unloading since most of the dumpings occurred at night as shown in Table 2. The two dumpings that occurred during daytime were on a holiday or weekend when boat operations were not scheduled. Basic coverage of the dump area was necessary and this was completed without contacting a barge unloading. On the morning of June 5 signs of a barge having dumped earlier in the morning were evident to the sample collecting crew.

Bacteriological results showed the coliform MPN's to be quite low, and there was no need to take more water samples covering the entire sample area. Sampling was suspended until contact could be made with a barge that was unloading.

The arrangements for making contact with a barge were difficult because advance arrival times given for a barge were in error. As a result of some persistant telephoning it was learned that a barge left Philadelphia on June 6 at 1425. According to the Corps of Engineers the one way trip to the dump site varies between 12 and 17 hours. Since no estimated time of arrival could be obtained from any source, plans were made to depart at 0230 June 7 to be certain of meeting the barge. After departure radio contact was made with the tug, Prince, enroute with the sludge barge, Raritan, and an estimated time of arrival of 0700 was given. The Wolverine then tied up until 0500 at which time it moved out to wait for the tow. The Prince and the Raritan arrived at the mouth of Delaware Bay at 0900 and proceeded to the dumping area. The barge began dumping at 1110 and was finished at 1135. Thus, the trip that was to take a maximum of 17 hours had taken 21 hours. No justifiable explanation for the extremely long time taken for the trip could be found in the tide or weather conditions.

The barge was followed and the path of dumping observed. The position of the vessel track was located by the use of Loran on the Wolverine. The path of the dump is shown on Figure 3 as a dashed line. The majority of the dump occurred outside of the dump area. The barge discharges while in motion to aid in dispersion and mixing of the sludge in the sea water. The Prince was not equipped with Loran and made its position determinations by the use of radar with Cape May and Cape Henlopen as references. Water samples were taken along the path of the dump to determine how rapidly the coliform counts decreased due to die-off and dilution. These samples were taken at the surface, mid-depth, and bottom. Two stations, 30 and 31, along the dump path were chosen and sampled repeatedly. The majority of the sludge appeared to settle rapidly.

BACTERIOLOGICAL RESULTS

The results of the bacteriological examination of the water taken on the regular sampling runs produced very few positive MPN greater than three. These positive results are shown in Table 3:

TABLE 3

Water Quality-Bacteriological
Samples of Positive Coliform MPN >3

Station Number	Date June 1967	Depth	Total Coliform MPN Per 100 ml	Fecal Coliform MPN Per 100 ml
2	1	M*	3.6	
4	2	M	3.6	
5	1	B**	9.1	
	2	B	9.1	3.6
6	1	M	3.6	
		B	9.1	
7	2	S***	9.1	
20	2	B	3.6	
21	2	S	3.6	
		M	3.6	
22	2	M	3.6	
23	5	B	1,100	43
	7	M	9.1	
		B	15	
32	7	B	7.3	

* Mid-depth
** Bottom
***Surface

Data covering all samples are in the Appendix.

Only 15 of the 85 regular run samples showed a positive total coliform MPN of greater than three and only one MPN was greater than 70. Fecal coliforms were shown to be present in only two of the samples. With the exception of two samples, one each at Stations 2 and 4, the samples with positive total coliform results were within a two mile radius of the center of the dump area. This was not surprising because samples taken in the New York Bight had shown similar rapid reduction of both total and fecal coliform counts. Seven of the 10 clam samples analyzed showed positive results for total coliform with only one greater than 2,400 MPN and 4 showed positive fecal coliform counts (Table 4).

TABLE 4

Clam and Associated Water Bacteriological Data

Date 1967	Sta. No.	Clam		Water	
		Total Coliform	Fecal Coliform	Total Coliform	Fecal Coliform
		MPN per 100 ml		MPN per 100 ml	
May 29	6	4,900	130	<3	<3
31	7	20	<18	<3	<3
31	8	<18	<18	<3	<3
31	17	20	<18	<3	<3
31	18	<18	<18	<3	<3
29	20	490	36	<3	<3
June		330	36	<3	<3
5	23	790	45	1,100	43
5	26	<18	<18	<3	<3
5	28	20	<18	<3	<3

Only one of the associated water samples taken with the clams had positive coliform MPN's. The MPN's in the clams might be attributed to the ability of the clam to concentrate coliforms or the possibility of survival of the coliforms in marine sediments. Bacteriological analysis of some bottom sediments should be done to ascertain if bottom sediments in the dump areas do maintain coliform populations. Greenberg (1956), reports that there is survival of enteric organisms in marine mud.

This aspect may be very important. Water quality a few inches above the bottom may be meaningless if sewage sludge deposits contaminate only the water in immediate contact with the bottom and the clams then draw their food supply from this contaminated source.

The samples taken in the dump path after the barge discharges showed a rapid reduction in coliforms regardless of whether it was caused mainly by dilution, die-off, or missing the heavier concentrations which possibly moved out of the area or were due to poor mixing. Station 23, June 5, showed the highest values for total coliform found. This was a bottom sample taken nearly four hours after a dump and points out the possibility of the discharged waste remaining concentrated and undiluted. The only sewage sludge sample analyzed resulted in a total coliform MPN of 7,000,000 and a fecal coliform MPN of 790,000. A sample taken immediately in the wake of the dumping barge produced total and fecal coliform MPN's of 150,000 and less than 3,000 respectively. Thereafter, samples taken at Stations 30 and 31, which were chosen because they were in the dump path, did not produce a total coliform MPN of greater than 100 as shown in Table 5. Difficulty in locating fisherman's markers observed along the dump path caused the delay in sample collection after the discharge was completed.

TABLE 5

Bacteriological Data Following Dumping of Sewage Sludge

Date 1967	Station No.	Time EDST	Depth	Total Coliform MPN	Fecal Coliform MPN	Time Elapsed Following Dumping (Minutes)	Temp. °C
June 7			S*	150,000	<3,000	1-2	
	30	1220	S	<3	<3	55	13.8
			M**	<3	<3		10.9
			B***	93	23		10.6
		1325	S	<3	<3	120	14.5
			M	3.6	3.6		11.1
			B	15	3.6		10.7
		1400	S	<3	<3	155	14.6
			M	3.6	3.6		10.6
			B	7.3	3.6		10.5
	31	1245	S	<3	<3	90	15.7
			M	3.6	<3		10.8
			B	3.6	<3		10.8
		1350	S	<3	<3	155	14.8
			M	<3	<3		10.7
			B	9.1	<3		10.8
		1420	S	<3	<3	185	14.1
			M	<3	<3		10.8
			B	<3	<3		11.0

* Surface
** Mid-depth
***Bottom

Barge began discharging at 1110 and was through at 1135.
Passed Station 31 at 1115.
Passed Station 30 at 1125.

HYDROGRAPHIC CONDITIONS

A surface slick, floating solids, and some odor remained in the sewage sludge discharge area for at least two hours after the dump. Visual observation indicated that the majority of the solids settled rapidly. It was not possible to follow the path of the dumped sludge as it settled but previous sampling, and samples at two stations in the apparent direction of sludge travel did not produce any high counts.

Perhaps some of the most distressing problems to the shellfish industry are due to the limited knowledge of the hydrographic variables in the discharge areas and the adjacent regions.

Several studies have been completed, but with only a few in reference to the specific problem. There is a question if the discharged sludge flows toward nearby surf clam beds on toward clams relay beds at the mouth of Delaware Bay. One commercial surf clam bed now in use lies five miles northeast of the center of the disposal area while the mouth of Delaware Bay is nearly twelve miles westward.

Tidal currents adjacent to and in the mouth of Delaware Bay indicate a strong tidal influence across the ten mile wide mouth. Velocities of nearly three knots can be found (U.S. Coast and Geodetic Survey, 1960). It is not unreasonable to assume that if any suspended materials are within three miles of the mouth they will be swept into the Bay during flood tide. Velocities of 1.0 to 2.0 knots could sweep materials across the relay beds within three hours. Redfield and Walford (1951) indicate that fine suspensions, such as can be found in sludge discharges, are transported for great distances. However, their survey also indicated that dilutions of the discharged material with sea water was more than 250 times within thirty seconds after dumping. The minimal rate of surface drift shown by Ketchum (1953) averaged four miles per day. Thus it would take three days to enter the Bay if a direct path was taken. The general current pattern is north-south along the coast, predominantly in a southerly flow. Work by Howe (1962) in the vicinity of Delaware Bay shows velocities of 4.3 miles per day at a depth of 30 feet and 5.9 miles per day at a depth of 86 feet and both moving in a southerly direction. This trajectory was also shown by Shuster (1963) in his diagram of the general current pattern along the Delaware coast as well as in drift studies by Bumpus (1965) and the U.S. Navy (1965). Miller (1952) conducted both theoretical and actual studies and arrived at a confused inshore eddy and a general southerly flow offshore.

The series of studies conducted since 1951 indicate that the original proposed location, one or two miles further south, is more desirable than the present dumping site. The normal southerly flow, plus the tremendous dilution factor appears to assure the safety of the surf clam beds to the north and the clam relaying beds in Delaware Bay from sewage sludge discharged twelve miles from shore in the present dump area. The surf clam

beds to the south will be in direct line to receive the discharged sludge carried by the prevailing southerly currents. Reference to Figure 1 shows heavy concentrations of surf clams south of Delaware Bay. A small amount of the finely suspended material will occasionally move shoreward, but is not likely to physically affect the relay beds within the Bay.

Discussion

The present danger to the Bay or adjacent surf clam beds arises from indiscriminate dumping. Dumping in unmarked areas is guesswork at best. The size of the present dumping areas and methods of discharge are not compatible. A barge usually discharges at maximum speed to achieve the greatest possible dilution, this means he must discharge his waste material within ten minutes or turn around and retrace his path. A larger area, clearly defined, would permit barge operators to keep within the dump site.

Adequate hydrographic data have been collected which permit an overall evaluation of the present site. Unless detailed, long-term current studies were contemplated, little additional information could be gained.

CHEMICAL ANALYSIS

Previous studies of waste disposal at sea deal mainly with industrial wastes. A report by Redfield and Walford deals with disposal of chemical wastes at sea and came to the following conclusions (Redfield, Alfred C., 1951). The waste studied was mainly an acid-iron waste. Its behavior when discharged was that of rapid dilution and neutralization of the acidity. The chemical properties of water would not be expected to be changed at any great depth or distance from the discharge point. There were no observable damaging effects on the populations of fish or bottom animals in the discharge area. No bottom accumulations had resulted during the relatively short period of disposal. The need for investigating each type of waste individually and continued monitoring for long-term effect and increasing discharges was cited.

Unpublished work was done off Delaware Bay for industrial waste disposal purposes (Ketchum, Bostwick H, 1953). A proposed and a permissive dump area was selected for slow settling industrial wastes. The main interest was in preventing contamination of mainland beaches and Delaware Bay. Surface currents were measured to assist in the determination of appropriate dump sites. At present the sewage sludge disposal is taking place in the permissive area defined by the Ketchum study which concludes that any dumping routine should be monitored for harmful effects.

RESULTS OF CHEMICAL ANALYSIS FOR HEAVY METALS

The NEMHSL chemistry section analyzed nine surf clam samples for heavy metals. Normal or expected concentrations of heavy metals in surf clams existing in waters believed to be uncontaminated by waste discharges have not been established. Therefore, normal values expected in hard clams are used for a base.

These values are listed as follows in Table 6:

TABLE 6

Normal Values for Heavy Metals Expected in Hard Clams

Metal	Mg/Kg Drained Weight of Shellfish Meats
Cadmium	<0.2
Chromium	<0.2
Cobalt	<0.2
Copper	<7.0
Iron	<50.0
Lead	<0.2
Manganese	<4.0
Nickel	<0.2
Zinc	<40.0

The values of Table 6 applied to the results of the analysis of the samples which are given in Table 7 present no abnormally high values in any of the samples with regard to cadmium, cobalt, copper, lead, manganese and zinc. The concentrations of iron found are also considered normal. All samples were found to be high in chromium and four of them high in nickel.

Work is being done at NEMHSL to establish normal heavy metals concentration values to be expected in surf clams gathered from areas believed to be free of contamination from waste discharges. Establishing these normal values will enable improved evaluation of the results found in this investigation.

TABLE 7

Chemical Analysis for Heavy Metals in Surf Clam Samples Taken off Delaware Bay

Date 1967	Sample Station	Cadmium	Cobalt	Chromium	Nickel	Lead	Copper	Manganese	Zinc	Iron
		All Results in Mg/Kg Drained Weight of Shellfish Meats								
May 29	6	<0.15	<0.10	2.00	<0.10	<0.15	2.00	2.35	10.25	120.15
May 31	7	<0.15	<0.10	7.49	3.72	<0.15	3.88	2.58	11.24	138.24
31	8	<0.15	<0.10	0.82	<0.10	<0.15	1.93	0.68	12.43	42.60
31	17	<0.15	<0.10	1.05	1.34	<0.15	2.82	0.86	12.64	47.80
31	18	<0.15	<0.10	1.28	<0.10	<0.15	2.38	2.79	12.69	96.88
May 29	20	<0.15	<0.10	4.47	3.28	<0.15	2.82	2.53	9.90	142.20
June 5	23	<0.15	<0.10	0.62	<0.10	<0.15	4.59	1.54	12.60	74.52
5	26	<0.15	<0.10	5.16	2.44	<0.15	2.07	2.27	12.72	91.59
5	28	<0.15	<0.10	2.19	<0.10	<0.15	1.16	2.16	12.69	88.00

CONCLUSIONS

The majority of the sludge appears to settle rapidly. There is a rapid reduction of coliform indicator organisms per unit of volume due to combined effects of dilution and die-off. The towing company hauling the sludge had difficulty in locating the specified dump area. One could not expect the dump to take place in the same area repeatedly under existing procedures. The positive coliform results were found to come from within a 2 mile radius of the center of the dump site. This indicates that the dumping took place in the vicinity of the specified dump area during the time of the investigation. No specific area could be designated as off limits to shellfish harvesting because of the uncertainty of where the sewage sludge would be discharged. Further studies of bacterial contamination would not be advisable until dumping operations improve in accuracy.

The bottom sediments may allow the coliforms to persist. No analysis to determine the fate of viruses was performed. Virus survival is an important item in all dealings with shellfish sanitation.

Findings under conditions existing during the period of investigation did not produce sufficient evidence of bacterial contamination over a widespread area to warrant moving the dump site unless it would be to move it beyond all shellfish harvesting grounds. In order to get beyond the good surf clam producing areas it would be necessary to dump about sixty miles offshore. The results of the study leave this as the only reason for moving the dump site at present. It may be advisable to move the dump site for future considerations in view of the impending increased dumping as more municipalities and industries seek an outlet for their wastes in the sea.

The value of the findings of such a limited investigation as was conducted off Delaware Bay, six days of bacteriological studies, should not be overestimated. It mainly points out that there is much more work necessary before any decision on waste disposal at sea can be reached.

The effect of the sludge as bottom sediment on the bacteriological and virological quality of the clams has not been investigated. The reason for high concentrations of heavy metals has not been explained.

The view of the section of the United States Public Health Service associated with Sea Resources concerning ocean disposal of industrial wastes and waste residue was clearly stated by Mr. Ralph J. VanDerwerker, Region II Program Chief, Water Supply and Sea Resources Program in a letter to the Supervisor of New York Harbor, Corps of Engineers, U.S. Army, October 23, 1967, and is quoted as follows:

"In view of the fact that we are now looking towards increased use of the ocean in search of new food sources, new pharmaceuticals, drugs, biologics, and the possible mining of the sea for metals, we can ill afford the indiscriminate use of the sea as a convenient dumping grounds for any and all wastes. Increased sedimentation in coastal areas was the initial factor in the gradual diminution of once extensive coastal oyster reefs, and any uninhibited dumping of wastes in the future may lead to the ultimate destruction of the whole of our last yet uncontaminated resource. Generally, the following more obvious and immediate points of waste disposal at sea should be considered:

1. Dilution will not always continue to work in our favor as heavy dumping of wastes continues.

2. All marine fauna will ultimately suffer.

3. Factors which enter the waste dumping picture, the ultimate effects of which we know very little about at this time are:

   a. stratification

   b. interaction

   c. current and current shifts

   d. storms

4. Packaging of wastes by solidification in concrete, envelopment in drums, or inclosure in similar materials may deteriorate through mixing and adsorbtion, resulting in a release of toxic materials to overlying waters.

5. Release of toxic materials will decrease the usage of the ocean as a food source and may cause frequent episodes of disease, such as the Japanese Minamata disease (caused by a mercurio-organic compound of industrial waste origin).

6. The various use of marine waters by ocean-going vessels of all types may eventually become impossible without the mandatory avoidance of waters in which such waste dumps are located.

7. Efforts of many oceanographic groups covering many different interests, and the increased funding now being made available on behalf of the world's oceans, will be for naught.

The burden of proof of the necessity of industrial waste disposal at sea should be placed on the dumper. Those desiring to dump should be required to present evidence that dumping at sea is the

only--not just the most economical--method of disposal. Steps should be taken to develop processes for reclaiming such materials resulting in their eventual use in the development of additional marketable products, or reclaiming for use in the manufacture of the original product. Steps such as these often have proven to be profitable, at least to the point of covering such treatment."

RECOMMENDATIONS

The following are recommendations and suggestions pertaining to better control and minimizing of harmful effects from sewage sludge dumping off Delaware Bay:

1. That closer regulation of the sewage sludge dumping operation be carried out. The following suggestions could aid in accomplishing this:

   a. Enlarge the present dumping area toward the south and adequately mark its location. The markers would assist in confining the dumping to a specified area.

   b. Adequate patrolling of the discharge area with suitable penalties for indiscriminate dumping will provide the maximum protection to the adjacent regions. The towing company would be required to notify the Coast Guard or someone who could monitor the dumping and check the barge location when a dump run is begun and ended.

2. Map the present discharge area to determine the following:

   a. The area affected by wastes.

   b. Movement inshore.

   c. Movement toward the south.

3. Long-term current studies would permit an evaluation of the percent of time the discharged wastes moved north to the present surf clam harvest area or west toward the Bay. The effect of the southerly flow on the possible future surf clam harvest beds to the south could then also be predicted.

4. Determinations of the survival and growth of indicator organisms in the bottom sediments should be done.

5. There could be a program worked out where two or three alternate dumping areas were established. The dumping would be done in one area closing it to all shellfishing. When the dumping was begun at the next area it would also be closed. The first area would be required to remain closed to shellfishing for a specified period until it was absolutely safe for harvesting shellfish. It could then be opened for shellfishing until sludge dumping was resumed in the area. Alternating two or more areas in this manner could be used to eliminate build-up of bottom sludge. At the same time it would not eliminate the shellfish resource because pollution conditions would not be continuous.

6. It might be possible to select dump sites where the shellfish population is small or nonexistent.

7. A surveillance program using some satisfactory indicator parameter that shows the effects of the sludge dumping should be established.

APPENDIX

TABLE A-1

Water Sample Data

Date 1967	Time EDST	Station No.	Depth	Total Coliform MPN Per 100 ml	Fecal Coliform MPN Per 100 ml	Temp. °C
June 1	1435	2	S*	<3	<3	12.1
			M**	3.6	<3	11.6
			B***40'	<3	<3	11.4
2	1445		S	<3	<3	13.8
			M	<3	<3	11.9
			B	<3	<3	11.9
June 1	1410	3	S	<3	<3	12.4
			M	<3	<3	11.5
			B 45'	<3	<3	11.3
2	1425		S	<3	<3	12.7
			M	<3	<3	11.8
			B	<3	<3	11.6
June 1	1355	4	S	<3	<3	12.9
			M	<3	<3	11.3
			B 45'	<3	<3	11.3
2	1345		S	<3	<3	13.7
			M	3.6	<3	11.6
			B	<3	<3	11.4
June 1	1325	5	S	<3	<3	12.9
			M	<3	<3	11.1
			B 54'	9.1	<3	10.8
2	1305		S	<3	<3	14.5
			M	<3	<3	11.4
			B	9.1	3.6	11.1
May 29	1230	6	B 45'	<3	<3	10.4
June 1	1015		S	<3	<3	11.3
			M	3.6	<3	10.8
			B	9.1	<3	10.8
2	0945		S	<3	<3	11.6
			M	<3	<3	10.9
			B	<3	<3	10.8

* Surface
** Mid-depth
***Bottom

Appendix (Cont'd.)

Date 1967	Time EDST	Station No.	Depth	Total Coliform MPN Per 100 ml	Fecal Coliform MPN Per 100 ml	Temp. °C
May 31	1315	7	B 55'	<3	<3	10.6
June 1	1250		S	<3	<3	12.2
			M	<3	<3	10.7
			B	<3	<3	10.6
2	1200		S	9.1	<3	11.9
			M	<3	<3	11.1
			B	<3	<3	10.3
May 31	1225	8	B 55'	<3	<3	10.1
June 1	1210		S	<3	<3	11.9
			M	<3	<3	10.6
			B	<3	<3	10.3
2	1130		S	<3	<3	11.3
			M	<3	<3	10.6
			B	<3	<3	9.2
May 31	0945	17	B	<3	<3	10.3
31	1115	18	B	<3	<3	10.0
June 1	0930	19	S	<3	<3	11.5
			M	<3	<3	10.6
			B 65'	<3	<3	10.5
2	0905		S	<3	<3	11.4
			M	<3	<3	11.1
			B	<3	<3	10.1
May 29		20	B 60'	<3	<3	
June 1	0945		S	<3	<3	11.4
			M	<3	<3	10.7
			B	<3	<3	10.6
2	0925		S	<3	<3	11.3
			M	<3	<3	10.9
			B	3.6	<3	10.4
June 1	1050	21	S	<3	<3	11.6
			M	<3	<3	10.9
			B 62'	<3	<3	10.9
2	1010		S	3.6	<3	12.2
			M	3.6	<3	11.0
			B	<3	<3	10.8

Appendix (Cont'd.)

Date 1967	Time EDST	Station No.	Depth	Total Coliform MPN Per 100 ml	Fecal Coliform MPN Per 100 ml	Temp. °C
June 1	1110	22	S	<3	<3	11.5
			M	<3	<3	10.9
			B 50'	<3	<3	10.9
2	1035		S	<3	<3	12.6
			M	3.6	<3	10.9
			B	<3	<3	10.4
June 5		23	B 53'	1,100	43	10.8
7	1500		S	<3	<3	15.7
			M	9.1	<3	10.8
			B	15	<3	10.7
June 5		26	B 45'	<3	<3	11.0
			B	<3	<3	
June 5	1315	27	B 60'	<3	<3	10.8
June 5	1350	28	B 50'	<3	<3	10.9
June 5	1435	29	B 45'	<3	<3	10.9
			S	<3	<3	
June 7	1445	32	S	<3	<3	14.9
			M	<3	<3	11.3
			B 56'	7.3	<3	10.9

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